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Transfer and Retroaction Effects of "Association Reversal" and "Familiarization" Training in Trouble Shooting

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INDUSTRIAL and military populations of employees and trainees contain several types of subgroups which differ in (presumably) psychologically significant ways. These differences can be utilized as independent variables in research directed towards discovery of *(a)* practical procedures of efficient organization of training programs in relation to work experience, and *(b)* laws describing the psychological relationships which underlie these procedures.

A general area in which these fortunate conditions prevail is that of trouble shooting. It happens, for example, that certain groups of Air Force aircraft and engine mechanics are taught about engine malfunction primarily in terms of *causes*, with which they learn to associate *symptoms*. Others begin with symptoms, and are taught to infer the possible causes. Later each type of group will be subjected to training or work experience which involves a reversal of the original sequence ("cause-symptom" or "symptom-cause"). This set of conditions can be designated *association reversal.*

It also happens that certain groups of mechanics learn to identify defective components and the names of these defects. Later on they may attend a technical school and learn to associate these names with symptoms of malfunction. Depending upon the way in which the diagnostic material is taught, i.e., as symptom-cause associations or cause-symptom, the earlier *familiarization training* received on the job could be designated stimulus training or response training.

The present study proposes to take advantage of these "natural" experimental conditions by determining their effects upon performance on specially designed "miniature diagnostic problems." Two types of problems were used to determine proficiency in engine diagnosis. They corresponded to the two types of association sequences in the training and work experience of mechanics referred to above, viz., *(a)* given the symptoms, the airman is to designate the cause(s), *(b)* given a cause he is to designate the symptoms. The nature of these problems, then, constitutes another independent variable.

If we make the assumption that learning associations in one direction, such as symptom-cause (S-C), is different from learning them in the reverse direction,

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then the learning of each constitutes a separate task and the paradigms of transfer and retroaction can be assumed to provide appropriate descriptions of the conditions that determine their interaction effects. From this point of view *association reversal* becomes a special case of these phenomena, depending upon the order in which the habits are learned in relation to the one that is tested for recall. A factor which may have significant psychological implications in relating both association reversal and familiarization training of mechanics to conventional studies of transfer and retroaction is that the associations of symptom and cause and of cause and symptom are divergent. In each case the cue is to be associated with several responses and when learned the responses presumably form a *habit family hierarchy*.

The present paper is a report of interrelated studies of both practical and theoretical problems, each of which will be described along with the experimental method used in its investigation and the results. Three variables were considered in the experimental designs: *(a)* the type of association practiced, *(b)* the sequence in which the different types of association were practiced, and *(c)* the relative amount of opportunity to practice. A sequence in which a mechanic practiced one task and then another and finally was tested for his recall of the first task was considered a *retroaction* paradigm. On the other hand, a sequence in which a mechanic practiced one task and then another and was finally tested for his recall of the second task was considered a *transfer* paradigm. It was possible to select, from a large number of examined airmen, subgroups which met the requirements of these experimental paradigms. The performance of these subgroups on the diagnostic problems was compared both to determine the effects of these variables in terms of the direction and extent of transfer and retroaction resulting from association reversal and familiarization training.

Problem

The appropriate sequencing of opportunities to practice the various components of technical jobs to provide maximum transfer and minimum interference is a persistent and fundamental problem. A necessary type of research in relation to this problem is the determination of the interaction effects which different opportunities to practice task components have upon one another.

Methodological Requirements

One reason why this type of research has not been conducted on a more extensive scale is the severe requirements that must be met in order for results to be clearly interpretable. One of these requirements is the appropriate characterization of the tasks which are separately practiced. Secondly, it is necessary to identify the sequences in which the appropriate opportunities to practice have occurred in the training and work histories of sizable groups of individuals for whom other potentially influencing factors are controlled. In addition, it is necessary to determine that the distribution of talent, as measured by an aptitude test, for example, is the same for the groups being compared. Having satisfied these requirements, it is possible to compare the performance of groups that are equated on a number of variables and different in a specified way on another variable.

In accomplishing these comparisons it is important to sample both problems and subjects rather broadly. In trouble shooting Air Force powerplants, both

line and dock experience are subject to a multiplicity of factors, and variations from individual to individual are to be expected. Depending upon the mechanic's job assignment and the length of time he works at this type of task, he will receive different amounts of practice on the various defects that might occur in a particular device. The frequency of occurrence of every defect, the length of time the man works on a "shred-out" job, and the types of shred-out jobs he is assigned are some of the factors that determine the amount and type of opportunity a mechanic has to practice the associations critical to the present research. The net result is that these experiences provide a variety of different degrees and types of practice with the possible diagnostic problems that could arise with a complex device such as a reciprocating engine.

Types of Associations

Divergent associations or multiple linkages. Two features of symptom-cause and cause-symptom associations appear to have important psychological implications. A symptom of malfunction, in many if not most complex systems or devices, is associated with more than one possible defect or cause. Also a defect may be indicated by more than one symptom of malfunction. These types of cue-response relationships have been designated *divergent* association. These multiple linkages between terms appear to be an important set of conditions with respect to learning, transfer, and retention of much technical information such as that used in diagnosing equipment failures. As compared with the learning, transfer, and retention of paired-associates types of connections, multiple linkages or divergent associations can be described as: *(a)* one to many; *(b)* many to one, and *(c)* many to many. In these terms, traditional paired associates are one-to-one linkages.

Sharing and overlapping linkages. Another presumably important feature of symptom-cause and cause-symptom associations is that a symptom (e.g., S_1) may be associated with a defect (D_1) that also produces one, or more, other symptoms of malfunctions (e.g. S_2); in addition, the reverse frequently is true. Thus the two symptoms (S_1 and S_2) also may be linked to a second defect (D_2). Many of the associations involved in learning diagnostic information, therefore, have *overlapping* linkages, i.e., terms in one set—symptoms—are linked to two or more terms in a second set—defects—and correspondingly, each term in the second set is linked to two or more of the same terms in the first set. In other words the pattern of linkages in both directions can be described as divergent connections (16).

If a single stimulus term is to be linked with two or more responses (one-to-many linkage), the relationship can be described as response sharing; conversely when two or more S terms are linked to one R term, they constitute many-to-one associations. The relationship will be designated stimulus sharing; similarly, many-to-many associations can be described as stimulus and response sharing.

Types of Practice

Three types of situations, with respect to the opportunity to practice particular types of relevant associations, figure in the comparisons made in the present study. Each type of association can be identified in terms of the setting permitting its practice, i.e., technical school training, line experience, and dock experience.

Technical school. The instruction in the reciprocating engine course which figured in

this study is probably typical of that found in many, if not most, courses dealing with the location of defective components in complex systems. That they would have this feature in common is particularly likely if they share the educational philosophy of this course which is to teach the student to "understand" the equipment rather than a set of "cookbook" procedures to be used in the solution of trouble-shooting problems. When malfunction states are discussed with an emphasis upon teaching for understanding, it is rather natural to use a so-called "logical" order of presentation. However, when alternative and equally logical accounts exist, a decision is required. In the case of diagnostic information there are two choices. One is an account of events in the temporal order of their occurrence which might be designated the *physical order*. The second is an account of events in the order of discovery in trouble shooting which might be designated the *diagnostic order*.

Using the physical order, a typical classroom discussion might be started by assuming that a particular defect exists in a system of the equipment. Next, the implications of this hypothetical defect with respect to the operation of the device would be traced. Each assumed defect serves to make possible a discussion of the operation of the equipment when the defect is present and a review of the normal operation of the system. While this procedure has much to recommend it, its psychological implications previously have not been submitted to analysis or experimental study.

In the advanced technical school which figured in this study, the emphasis was upon teaching symptoms produced by defects or causes, i.e., C-S associations, and less stress was given to the reverse direction of association, i.e., S-C associations. This emphasis can be represented as C-S $>$ S-C.

Line experience. Field observations and interviews with mechanics and instructors who had job experience[2] permitted the characterization of line and dock work in terms of the predominantly, if not exclusively practiced cue-response relationships which these jobs permit. Line experience may be characterized as predominantly S-C learning. In performing this type of work the mechanic begins to solve a diagnostic problem knowing the indications of malfunction and is required to determine the defect producing the particular symptoms he observed.

Dock experience. Dock experience may be described as C $>$ S learning since it provides the mechanic with an opportunity to learn C terms or the labels associated with causes (or defects) and with little if any opportunity to learn S terms (or the labels of symptoms). In working on the dock, the mechanic performs preventive maintenance. He takes apart engine components and inspects them to determine whether there are defects present. In doing this it is likely that he would learn the names of the defects he observed; however, he would not be required to practice the association of symptoms with these defects or vice versa.

[2] These are described and summarized in unpublished technical reports transmitted to AF Personnel and Training Research Center in 1952 and 1953.

Sequences of Air Force Training and Experience in Trouble Shooting

At the time the present study was conducted it was possible for a variety of combinations of training and work experience to occur; however, a sizable but varying proportion of airmen in the advanced reciprocating engine course would be "pipeline" students. These men were sent directly to the advanced course from a basic school without intervening job experience. Others in the same class in technical school may have acquired different amounts and types of related work experience before attending the advanced course. Still others would have completed the advanced course as pipeline students and then acquired job experience.

The *phenotypic* variables (7, p. 11) associated with the problems studied are *(a)* training and work sequence, *(b)* amount of work experience, and *(c)* type of work experience. In addition to the determination of the effects of these variables as such on the recall of C-S and S-C associations, appropriate comparisons also can be made which take into consideration the sequence in which the various types of associations were practiced, i.e., *genotypic* variables. When the sequence is taken into consideration and related to the type of diagnostic problem used to measure retention, the conditions are met for either a transfer or retro-

action design involving association reversal or familiarization training.

Transfer effects. The performance of pipeline students on problems which require the recall of causes of engine malfunctions, given the symptoms (S-C or symptom-cause problem), and the recall of symptoms that could result from stated causes (C-S or cause-symptom problems) will reflect the level of proficiency generated by training in the advanced reciprocating engine course. The scores of this group therefore could be used as a control measure for the purpose of comparing groups with different work experience, all of whom attended the advanced reciprocating engine course. In this way it is possible to determine the relative amount and direction of delayed transfer effects resulting from the various conditions of work.

The notion of delayed transfer effects as used here refers to the fact that the effects of transfer are being measured after the trainee has had considerable opportunity to practice the second task on which the test of transfer is based. This condition is different from the determination of transfer after various intervals between learning Task 1 and Task 2. Data from laboratory studies indicate that the intertask interval has very little effect on the amount of transfer that results from training on the first task (2, 3, 8, 12, 15). This is a fortunate circumstance, since in this study it was not possible to control the intertask interval.

Transfer effects attributable to *association reversal* could be determined under several conditions. For example, both brief and longer *line* experience can serve as the first task, in which case the scores from the C-S problems could be used as the dependent variable. Similarly the transfer effect of advanced technical school training can be determined from the scores on S-C problems for the mechanics who received their job experience (S-C associations) after attending technical school.

There have been several studies of transfer after different amounts of practice on Task 1 (8, 12). The typical finding is that increasing amounts of practice on the first task results in increased amounts of positive transfer effect. In fact, even if a small amount of practice on Task 1 resulted in negative transfer effects, large amounts of practice have produced positive transfer effects (8). This finding would lead to the expectation that the same might hold in the case of association reversal.

The transfer effects of familiarization training also can be determined for those who had dock rather than line experience. The scores on the C-S problems provide an index of the effects of *stimulus training* and those based upon S-C scores represent the effects of *response training*. In both cases the conditions depart from those conventionally studied since *(a)* divergent overlapping associations are involved rather than simple S-R connections, and *(b)* training was probably selective.

Results from studies of predifferentiation training (1, 6, 9, 10, 14) would lead to the expectation that stimulus training might produce positive transfer effects if the cue stimuli are confusable; however, if they are not confusable, then it would appear that the results of "associative inhibition" studies (8) would apply and the learning of C-S associations after learning the names of defects would be slower than if the student had not had the dock experience. Since there are no data upon which to base a decision about the confusability of these terms, it is not possible to state in advance which one of

these notions would apply in the present research.

Since appropriate data are not available, the effects of response training can not be predicted. In addition to the factors of divergence and overlap, among the S-C and C-S associations, the response training may have been selective, i.e., disproportionally distributed, as a consequence of: *(a)* the differences in the probability with which the various defects appeared, *(b)* the job assignments of the men, and *(c)* the emphases in school.

Retroaction effects. The conditions obtaining for various groups of Air Force mechanics also permit the determination of the retroaction effects of association reversal under some specifiable conditions. Before attending the advanced reciprocating engine course the mechanics with line experience learn S-C associations, and then in school they learn C-S associations. The recall scores on S-C problems represent the retroaction effects of association reversal when compared with those of the pipeline students. Also for groups differing in the amount of work experience, it is possible to determine the extent of retroaction when the opportunity to practice the earlier learned task varied in amount.

The traditional concern of retroaction studies has been with the conditions that are related to interference effects produced by the learning of an interpolated task. This emphasis is probably explained by the historical interest in forgetting. The most commonly accepted explanation of losses in ability to perform a task is that it is due to the interpolated learning of an interfering task (8, 12). Examples of conditions found to be significant in this respect are the interrelationships between the stimuli in the two tasks, between the responses, and between S-R associations in each case. With one exception, association reversal is one type of intertask relationship previously overlooked (13). Knowledge of the retroaction effects of this variable under the conditions obtaining for various groups and trainees therefore would be of both practical and theoretical interest.

Method

Toops's (17) addend coding procedure was used to identify the individuals comprising the five experimental groups that were compared. This was made possible by including a biographical questionnaire in the problem booklets.

Taxonomic tables were prepared for the two groups of airmen used in this study. In both tables four classes of experience were used, each of which was represented by a number of variations. In the taxonomic table for the airmen in technical school the experience classes were: *(a)* basic training school, *(b)* type of engine experience, *(c)* amount of experience in months, and *(d)* type of job preceding school. For the airmen working as mechanics the first three classes were the same; the fourth was present job assignment.

Experimental Paradigms

Two different but interrelated sets of comparisons figured in the present study, i.e., the "phenotypic" and "genotypic." One set was designed to obtain information related to the practical problems of organizing technical school training and job experience; the other set was used to obtain information related to problems of transfer of training and retroaction under conditions of association reversal and familiarization training.

Sequences of technical school and job experience. This first paradigm was used to determine the relative effects of differ-

ent sequences of work experience and technical school training. Two different sequences were compared with the performance of pipeline students on the same problems. The comparisons that were made can be summarized as follows:

Group		Experience and Training		Recall Tests
Code	Description	1st task	2nd task	
CG	Controls (pipeline students)	(None)	Advanced training C-S>S-C	(a) S-C (b) C-S
EA	Experimental condition *A*	Brief line experience S-C	Advanced training C-A>S-C	(a) S-C (b) C-S
EB	Experimental condition *B*	Advanced training C-S>S-C	Brief line experience S-C	(a) S-C (b) C-S

Amount of work experience. The paradigm used to determine the effects of amount of work experience preceding technical school training was:

Group		Experience and Training		Recall Tests
Code	Description	1st task	2nd task	
CG	Controls (pipeline students)	(None)	Advanced training C-S>S-C	(a) S-C (b) C-S
EA	Experimental condition *A*	Brief line experience S-C	Advanced training C-S>S-C	(a) S-C (b) C-S
EC	Experimental condition *C*	Longer line experience S-C	Advanced training C-S>S-C	(a) S-C (b) C-S

Type of work experience. The paradigm used to determine the effects of differences in the type of work experience was:

Group		Experience and Training		Recall Tests
Code	Description	1st task	2nd task	
CG	Controls (pipeline students)	(None)	Advanced training C-S>S-C	(a) S-C (b) C-S
EA	Experimental condition *A*	Brief line experience S-C	Advanced training C-S>S-C	(a) S-C (b) C-S
ED	Experimental condition *D*	Brief dock experience C>S	Advanced training C-S>S-C	(a) S-C (b) C-S

Transfer effects. Examination of the first paradigm indicates that the C-S scores of the EA group on the recall tests represent the delayed effects of transfer from S-C training, *association reversal.* These mechanics had learned S-C associations during their brief period of work on the line which preceded their training in advanced technical school. This latter training provided them with the opportunity to learn C-S associations. Therefore if the C-S recall scores of the EA group are compared with those of the pipeline students (CG), it is possible to determine the amount and direction of the transfer effect of their work experience. If the C-S scores of the EA group were to be smaller than those of the CG

it would indicate that the line training which the EA group had received before attending technical school had a negative transfer effect; the reverse would indicate positive transfer.

The second paradigm deals with the effects of different amounts of similar experience prior to taking the advanced technical school course. The C-S recall scores are an index of the delayed transfer effects of line experience. This latter experience permitted the mechanics to practice S-C associations. This was the Task 1 condition for both EA and EC groups, but in the former case the *amount* of opportunity to practice the S-C associations was less than in the latter.

In a similar way the transfer effects of *familiarization* training can be determined under two different conditions. These are provided by the third paradigm through the comparisons of the ED group with the CG on the C-S problems. This comparison indicates the effects of stimulus training, and on the C-S problems the comparison of these groups indicates the effects of response training.

Retroaction effects. In the first paradigm the S-C scores of the EA group in relation to those of CG represent the retroaction effects of advanced technical school training. Similarly, the C-S scores of the EB group in relation to those of CG indicate the amount and direction of the retroaction effects of brief line experience.

In the second paradigm the S-C scores of the EC group in relation to those of CG represent the retroaction effects of advanced technical school training after a longer opportunity to practice S-C associations than that available to the EB group in the first paradigm.

Subjects

A total of 297 airmen were examined while at technical school and an additional 80 while working as mechanics (at two different air bases). The five groups which would permit the comparisons indicated in the paradigms are presented in Table 1.

The technical school provided sufficiently large numbers of airmen in CG (ulstrith 284),[3] EA group (ulstrith 845), EC group (ulstrith 900), and ED group (ulstrith 1945); and the two air bases provided samples, in the EB group (ulstrith 30), sufficiently large to permit comparisons with the others as indicated. Of the 377 airmen who were examined however, only 178 met the requirements of this study. These were: *(a)* appropriate biographical history to permit classification into one of five ulstriths, and *(b)* completion of all the problems.

Descriptions of only the critical biographical data are presented in Tables 1 and 2. To save space, complete descriptions of the biographical variables used in the taxonomic tables are not presented in this report. Table 1 presents the information that is important to the present study.

The clerical and mechanical aptitude indices from the Airman Classification Test Battery were secured for all airmen.

[3] Ulstrith is a term coined by Toops (17). An ulstrith code number is the sum of addends assigned to the variations in the classes of biographical data considered to be relevant and important to the study. "Addends are numbers which when added yield a code number uniquely identifying the ultimate breakdown society to which a given person belongs" (Toops, 17, p. 41). Toops indicates the rules to be used in assigning these numbers; however, the needs of a particular study determine the events and variations of each which are included in the taxonomic table.

TABLE 1

COMPOSITION OF AIRMEN SAMPLES IN TERMS OF SELECTED BIOGRAPHICAL INFORMATION*

Classes of critical biographical data	Ulstriths				
	At end of training				On the job
	CG 284	EA 845	EC 900	ED 1945	EB 30
Job experience					
Student	x				
Line mechanic		x	x		x
Dock mechanic				x	
Amount of experience (in months)					
None	x				
0 to 8.9		x		x	x
9 to 17.9			x		
Engine experience					
None	x				
R-4360 only		x	x	x	x
Sequence of school and job					
School before job experience	x				x
School following job experience		x	x	x	

* A total of 297 airmen were examined while in training and 80 while working as mechanics at two SAC bases. Of this total, 178 met the requirements of this study. The numbers given each problem-booklet form were as follows:

Form A (94)	31	25	10	17	11
Form B (84)	32	14	10	19	9

Problems—Recall Test Materials

The problems used were adapted from those employed in the evaluation of trainees in the reciprocating engine course given in technical school. They are particularly modeled after the type of problem used to examine trainees in the trouble-shooting phase of the Advanced Reciprocating Engine Course. The problems were systematically edited and revised. This was a cooperative enterprise involving personnel associated with the course and the authors.

Description of problems. Twenty-one problems were of the type "List the symptoms caused by ————." These are referred to as the cause-to-symptom (C-S) problems. The trainee is required to associate a list of symptoms with a given cause. The remaining 29 were of the type "List the possible causes of the following symptom: ————." These were described as symptom-to-cause (S-C) problems.

Problem booklets. Since it was apparent that the presentation of 50 problems of these types to any one airman would overburden him, particularly since each list of symptoms and causes may be fairly long, it was decided to divide the total set of problems into two equivalent sets. Accordingly, two sets of the problems were assembled into booklets each of which contained 25 different problems. Form A, Section I contained 10 problems of the C-S type, and Section II contained 15 S-C; Form B contained 11 and 14 problems of each type, respectively. The two forms were made as comparable as possible.

Each form had the same set of initial pages. Each airman filled in the blanks on these pages with his biographical data. All booklets also contained the same sample problems and instructions

to the airman. The two forms differed in that they did not contain common problems.

The problems were all of the write-in type. Either a symptom or a cause of a malfunction was stated and the airman was obliged to recall and write down as many relevant responses as he could think of.

Classification of Responses and Scoring

Since a "consensus" of expected right answers was available for every problem, it was possible to classify most of the correct responses under each of these. Where responses did not fit under a rubric of the scoring key, they were classified as either ambiguous or uncertain. Every problem was separately tabulated.

A classification system for responses to C-S problems. Four general categories of response were: right, wrong, ambiguous, and uncertain. Under each of these rubrics there were response types under which individual "tokens" were tallied. The consensus of expected right answers serves as the types for the general category. Those for the wrong responses were generated by the data, as were the ones included under the other two general categories. An ambiguous response was one which we were not able to decide upon with respect to its correctness or incorrectness because the answer was incomplete. The uncertain responses were those which were apparently complete but as stated were assumed to be highly improbable. In most cases a response was classified as uncertain when the magnitude or degree of the defect or cause would be the critical determinant of the presence or absence of the symptoms and the trainee failed to say anything about this.

The various response types under each of these general classes were organized under each of three subclasses: *(a)* symptoms, *(b)* malfunction conditions or states, and *(c)* defective physical units or causes. Only symptoms and malfunction conditions met the requirements of a correct response to the C-S problems (Sections I in Forms A and B).

A classification system for responses to S-C problems. The processing and analysis of the responses to questions in Section II were conducted in the same general manner as described for Section I. The two major categories were right and wrong, and the latter was subdivided into: *(a)* wrong causes, *(b)* ambiguous causes, and *(c)* symptoms. No attempt was made to subdivide these problems according to the powerplant systems since a given symptom may have been the result of defects in any one of several different systems. There were 15 problems of this type in Form A and 14 in Form B.[4]

Scoring of C-S problems. The responses under the categories ambiguous and uncertain were given a weight of zero. For Section I arbitrary values of plus one were assigned to every right response and minus one to every wrong response. The score for every airman was an algebraic total and therefore could be zero, or a minus or plus value depending upon the relative frequency of correct and incorrect responses. A constant positive integer—10—was added to all scores to make them all positive and larger than zero.

Both Forms A and B were scored in the same way; however, Form A contained 10 and Form B 11 C-S problems. The scores for two different subsets of problems were determined depending upon whether they were *fuel system* problems or problems from the other

[4] One problem, Number 5 of Form A, Section II, was not scored.

engine systems (general). This separate analysis was made in anticipation of differences in sensitivity to the effects of the experimental conditions. The fuel system happened to be the only one with a sufficient number of problems to warrant separate scoring. This was simply the joint result of the problems that were available to work with and the editorial processing.

Both Forms A and B were scored using the simple binary weights (± 1). An algebraic total score was computed for every airman and these scores were summed for each group (ulstrith).

Procedure

Arrangements were made with the instructional supervisors of the Reciprocating Engine Division in technical school to administer the problems during class hours to all trainees enrolled in the Engine Course. The last (fourth) phase of the course was chosen as the one most suitable for the experiment. Ten separate classes were examined on the sixth day of the last phase.

The instructors were asked to introduce the problems as though they were a regular part of the course requirement. It was pointed out to the instructors that a student might ask if his score would count in his final grade. In anticipation of this the instructors were told to answer in an equivocal manner, such as "All your work is important here." This answer at the very least did not specifically identify the problems as an experimental device and probably insured an adequate level of motivation.

Instructors passed copies of the instruction sheets to their students. They then read aloud the instructions while the students followed by reading their own copies. At the appropriate place in the directions the instructor distributed the Problem Booklets to the students.

The Problem Booklets previously had been arranged in consecutive numerical sequence which in effect resulted in the distribution of Forms A and B to alternate members in the classroom. This procedure allowed approximately equal distribution of Forms A and B at any one testing, and also helped to reduce the amount of cooperative work among the trainees. Also it was assumed that this procedure would result in approximately randomized distribution of problems over the available talent. There was no convenient way of determining in advance of the experiment the actual ability levels of the individuals in every class. A great deal of investment in time, examining personnel records, and tracing individuals through class rosters would have been necessary to make this possible. Reliance was placed, therefore, upon the probable chance distribution of talent over the two forms of problems rather than upon any selection procedure involving the identification of individuals. A check was made of the homogeneity of the groups by later examining their aptitude scores.

First the trainees filled out the personal history items. Then the instructor told them that they had 60 minutes to complete the 25 problems in their booklet. Following this he told them to begin. At the end of 60 minutes, trainees were told to close their booklets and place them on their desks where they would be collected by the instructor.

During each session the research project representative sat at the back of the room and observed the procedure used. He was prepared to note disturbances and exceptional conditions on a specially prepared check sheet.

While the testing sessions were being conducted in technical school, arrangements were made to have the problem booklets administered to a small sample of airmen who were working as mechanics. As far as possible, the procedure used was the same as that employed in technical school.

Results

One set of groups of subjects (ulstriths 284, 845, and 30) made possible the determination of the effects of *order of experience* with respect to school training and work experience as indicated in the first paradigm. Another made possible the determination of the effect of different *amounts of experience* before attending technical school (ulstriths 284, 845, and 900). A third set made possible the determination of the effects of different *types of experience* (ulstriths 284, 845, and 1945). An analysis of the pertinent constant and variable factors in the experience of these five groups is indicated in Table 2.

Subjects in ulstrith 284, the pipeline students, were designated as CG in the paradigm analysis. They are included in

TABLE 2

DESCRIPTION OF PARAMETERS DETERMINING COMPARISONS OF RESPONDENT ULSTRITHS

Groups Compared*	Constants**			Variables		
	School sequence	Type of experience	Amount of experience	School sequence	Type of experience	Amount of experience
(1) 284, 845, 30		x	x	x		
(2) 284, 845, 900	x	x				x
(3) 284, 845, 1945	x		x		x	

* Ulstrith numbers. CG is ulstrith 284, EA is 845, EB is 30, EC is 900, and ED is 1945.

** An important feature of the use of Toops's method is the control permitted by identifying potential variables which can be held constant while a single "molar" variable is studied. The parameters identified as constants in this table were constant for the groups compared in a particular analysis. The addends procedure resulted in five ulstriths for which the individuals had a large number of common biographical events.

each comparison to serve as a standard or control group.

Aptitude indices. The mechanical and clerical aptitude indices of these groups were tabulated as a control measure. When these aptitude indices were examined for statistical significance using the distribution-free test described by Mood (11, p. 398), neither of the analyses —groups tested with Forms A and B— resulted in a significant X^2 (minimum confidence level of five per cent). This means that all groups were equivalent in talent and therefore that a difference in their S-C and C-S scores is not attributable to aptitude.

Analysis of Variance of Ulstrith Scores

Three sets of variance analyses were computed. They corresponded to the paradigms previously described. In each set there were three $3 \times X$ designs in which the first factor consisted of the three *groups* (ulstriths) in the paradigm and the second was a set of *problems.* There were six analyses for every paradigm—three types of problems in each of two separate sets or booklet forms. Since an airman responded to all of the problems in a booklet and every booklet contained three sets, the second factor in the analyses of variance represented repeated measurements on the same subjects. Therefore the problem mean square was evaluated in terms of the pooled *Ss* × problems mean square (4, pp. 289-296). Section I of both Forms A and B contained the C-S problems, and these constituted one analysis for every paradigm. Section II contained two different types of problems: *(a)* S-C general systems except fuel, and *(b)* S-C fuel system. Each of these three sets of problems in each form constituted a separate analysis of variance for a particular set of three subject groups.

The results of these analyses are presented in Table 3 summarized under the three phenotypic variables: *(a)* schoolwork sequence, *(b)* amount of line experience, and *(c)* type of experience. The two principal variance components are: *(a)* ulstrith differences, and *(b)* problem differences. The individual problem means are presented in Tables 4 and 5.

Problem differences. The most consistent result from the variance analyses was the significant difference between problems. (See Tables 3, 4, and 5.) In every analysis, the between-problems variance was sufficiently large to produce significant *F* ratios (beyond the .01 level).

The methodological implication of this result is clear. It indicates the hazard

TABLE 3

SUMMARY OF RESULTS FROM VARIANCE ANALYSIS OF RECALL SCORES ON PROBLEMS

Paradigm	Variable	Groups (ulstriths)	Type of Problem	Booklet	System	F Ratios			
						df b/w	Between ulstriths	*df* b/w	Between problems***
1	School-job sequence	CG, EA, EB (284, 845, 30)	S-to-C	A	General	2/64	13.22***	13/832	60.61
			S-to-C	B	General	2/52	4.20**	13/676	24.25
			C-to-S	A	General	2/62	2.88*	5/310	22.45
			C-to-S	B	General	2/52	3.86**	5/260	34.54
			C-to-S	A	Fuel	2/63	5.35*	3/189	69.65
			C-to-S	B	Fuel	2/52	.69	4/208	9.77
2	Amount of line experience	CG, EA, EC (284, 845, 900)	S-to-C	A	General	2/63	.55	13/819	60.11
			S-to-C	B	General	2/53	.56	13/689	26.86
			C-to-S	A	General	2/62	.29	5/310	22.48
			C-to-S	B	General	2/52	.21	5/260	30.36
			C-to-S	A	Fuel	2/63	4.85**	3/189	69.00
			C-to-S	B	Fuel	2/55	.80	4/212	13.02
3	Type of experience	CG, EA, ED (284, 845, 1945)	S-to-C	A	General	2/70	.27	13/910	65.68
			S-to-C	B	General	2/62	.68	13/806	31.51
			C-to-S	A	General	2/68	.59	5/340	27.79
			C-to-S	B	General	2/62	1.41	5/310	38.77
			C-to-S	A	Fuel	2/69	2.18	3/207	73.68
			C-to-S	B	Fuel	2/63	.26	4/244	12.66

* Probably significant, *F* lies between the 10 and 5 per cent levels for the appropriate degrees of freedom.
** Significant, *F* lies between the 5 and 1 per cent levels for the appropriate degrees of freedom.
*** Very significant, *F* lies beyond the 1 per cent level for the appropriate degrees of freedom.

of generalizing results from a small set of problems to any other set. The R-4360 powerplant is sufficiently complex to make it very unlikely for any one to achieve high *general* level of proficiency in trouble shooting. Mechanics probably learn some problems, say the more frequent ones, very well, and others a little or not at all, depending upon the opportunities provided by their training and job assignments.

School-job sequence. Five out of six *F* ratios were significant in the analyses of variance computed to determine the effects of the school job sequence. (See Table 3.)

TABLE 4

MEANS FOR SYMPTOM-TO-CAUSE PROBLEM*

Problem No.	Form	Ulstriths** 284 CG	845 EA	900 EC	1945 ED	30 EB	Problem No.	Form	Ulstriths** 284 CG	845 EA	900 EC	1945 ED	30 EB
1	A	14.06	13.04	14.09	13.83	10.96	1	B	12.84	13.07	12.00	13.11	11.56
2	A	13.15	13.35	14.18	13.51	10.86	2	B	11.59	12.29	13.3	12.16	10.78
3	A	12.56	12.44	13.76	12.82	10.51	3	B	10.00	10.36	11.1	10.89	10.33
4	A	19.19	17.86	18.23	18.21	14.61	4	B	12.72	12.78	12.3	12.21	12.00
5	A	14.42	14.49	14.99	14.76	11.74	5	B	10.09	10.00	11.0	10.21	9.56
6	A	14.47	14.44	15.04	13.42	11.39	6	B	10.25	10.21	10.2	9.63	10.11
7	A	12.51	12.76	13.58	13.06	10.79	7	B	11.18	10.93	11.4	10.87	10.56
8	A	13.20	13.29	13.10	13.19	12.27	8	B	9.41	9.71	8.9	9.26	10.11
9	A	12.89	13.49	13.09	12.29	11.50	9	B	10.09	10.07	9.1	10.63	10.22
10	A	12.67	12.65	12.48	11.92	11.81	10	B	11.41	12.29	11.8	11.74	10.80
11	A	9.88	10.15	9.74	9.51	10.61	11	B	10.81	10.71	10.4	10.84	9.78
12	A	13.31	13.33	13.00	13.04	11.95	12	B	10.91	11.43	11.9	10.84	10.56
13	A	13.50	13.28	14.51	12.24	11.17	13	B	12.34	12.00	11.8	12.52	10.89
14	A	9.89	10.17	10.49	10.52	10.12	14	B	12.03	11.86	11.9	12.63	11.33
Means		13.26	13.26	13.66	13.02	11.45	Means		11.12	11.26	11.22	11.25	10.62

* Differences were significant for both Forms A and B among ulstriths 284, 845, and 30 demonstrating the differences in school-job sequence (see Table 3).
** See Table 1 for description of groups.

TABLE 5

MEANS FOR CAUSES-TO-SYMPTOM PROBLEMS

Problems		Ulstriths					Problems		Ulstriths				
Number	Form	284 C	845 EA	900 EC	1945* ED	30 EB	Number	Form	284 CG	845 EA	900 EC	1945* ED	30 EB
						Fuel system**							
3	A	10.26	11.08	11.20	10.75	6.19	3	B	11.06	11.50	12.00	11.56	11.00
4	A	10.58	9.96	12.30	11.19	5.75	4	B	11.94	12.29	13.00	11.72	11.67
5	A	13.71	13.72	15.20	14.81	7.88	5	B	11.53	11.70	12.50	12.22	11.00
6	A	13.77	13.52	14.30	14.19	7.50	6	B	10.31	10.43	9.20	9.50	10.00
							10	B	11.75	11.71	12.20	11.22	11.44
Means		12.08	12.07	13.25	12.74	6.83	Means		11.32	11.54	11.78	11.24	11.02
						General***							
1	A	11.60	12.40	12.10	12.19	9.60	1	B	11.53	11.57	11.67	12.21	9.78
2	A	9.83	8.60	9.90	9.94	10.00	2	B	9.22	9.00	9.44	9.89	8.22
7	A	12.47	10.30	12.00	13.00	12.00	7	B	10.25	10.00	9.67	10.26	9.22
8	A	11.00	9.13	11.20	11.06	10.20	8	B	10.81	10.64	10.67	10.63	10.11
9	A	10.83	8.97	11.90	11.25	10.70	9	B	11.88	11.71	11.67	12.47	11.55
10	A	10.07	8.13	10.00	10.19	9.50	11	B	9.63	9.36	9.89	9.53	9.67
Means		10.97	9.59	11.18	11.27	10.33	Means		10.55	10.38	10.50	10.83	9.76

* This group did not enter into either of the variance analyses that produced significant effects among ulstriths.
** Significant differences in amount of line experience (284, 845, 900), see Table 3.
*** Significant differences in school-job sequence (284, 845, 30), see Table 3.

Amount of experience. These ulstriths differed sufficiently to produce a significant *F* ratio for the fuel system C-S problems (Form A).

Type of work experience. No significant *F* ratios were obtained from these comparisons.

Transfer Effects

In determining the effects of genotypic variables under conditions of association reversal and familiarization training, the relative amounts of transfer and their direction were computed by obtaining the differences between the experimental groups and the controls, dividing this by the score of the controls (pipeline students—CG) and multiplied by 100. These data are presented in Tables 6 and 7.

School-job sequence. If we examine the transfer effects reflected by the C-S

TABLE 6

PERCENTAGE OF TRANSFER EFFECTS RESULTING FROM "ASSOCIATION REVERSAL"

Groups Compared with Ulstrith 284 (control group)		Training (Task 1)		Recall Test (Task 2)		Transfer Effects	
Group	Ulstrith	Type	Amount	Form	Problems	Negative	Positive
EA	845	Line	(0 to 8.9 mo.)	A	C-S (general)*	0.08	
				B	C-S (general)*		1.94
				A	C-S (fuel)	12.58	
				B	C-S (fuel)	1.61	
EB	30	Technical school		A	S-C	13.65	
				B	S-C	4.49	
EC	900	Line	(9 to 17.9 mo.)	A	C-S (general)		9.69
				B	C-S (general)		4.06
				A	C-S (fuel)		1.91
				B	C-S (fuel)	0.47	

* See text for distinction between general systems and fuel system problems.

TABLE 7

PERCENTAGE OF TRANSFER EFFECTS RESULTING FROM "FAMILIARIZATION TRAINING"

Group Compared with Ulstraith 284 (control group)		Training (Task 1)	Recall Test (Task 2)		Transfer Effects	
Group	Ulstrith		Form	Problems	Negative	Positive
ED	1945	Response training	A	S-C	15.16	
			B	S-C		1.16
		Stimulus training	A	C-S (general)*		5.46
			B	C-S (general)	0.71	
			A	C-S (fuel)		2.73
			B	C-S (fuel)		2.65

* See text for distinction between general systems and fuel system problems.

scores, we find a sizable amount of negative transfer for the EA group (ulstrith 845) on the fuel system problems (Form A). Also, there were sizable negative transfer effects obtained with group EB (ulstrith 30) as indicated by the S-C scores.

It appears that association reversal can produce sizable negative transfer effects regardless of whether the mechanic first learns S-C associations on the job and the C-S information in school, or vice versa. These results were obtained with independent groups that had had nine months or less of work experience on the line. These data (Table 6 and Fig. 1) could be interpreted as an indication that: *(a)* a small amount of job experience before advanced technical school training may interfere with school performance on C-S problems, and *(b)* more importantly, school training which emphasizes C-S associations may produce habits that interfere with the mechanic's performance of his job up through the first nine months.

Amount of experience. The data showed positive transfer effects for the more experienced line mechanics—group EC (ulstrith 900). This was found for the fuel system C-S problems (Form A) as well as for the general systems problems (Forms A and B). These mechanics had from 9 to 18 months of line experience

TABLE 8

RETROACTION EFFECTS ASSOCIATED WITH INTERPOLATED SCHOOL TRAINING AND "WORK" EXPERIENCE

Groups Compared with Controls (ulstrith 284)		Problems		Retroaction	
		Form	Type	Source	Percentage
EA	845	A	S-C	School training	0.0
		B	S-C	School training	+1.26
EC	900	A	S-C	School training	+3.02
		B	S-C	School training	+0.90
EB	30	A	C-S (general)	Work experience	−43.46
		B	C-S (fuel)	Work experience	−5.83
		A	C-S (general)	Work experience	−2.65
		B	C-S (fuel)	Work experience	−7.49

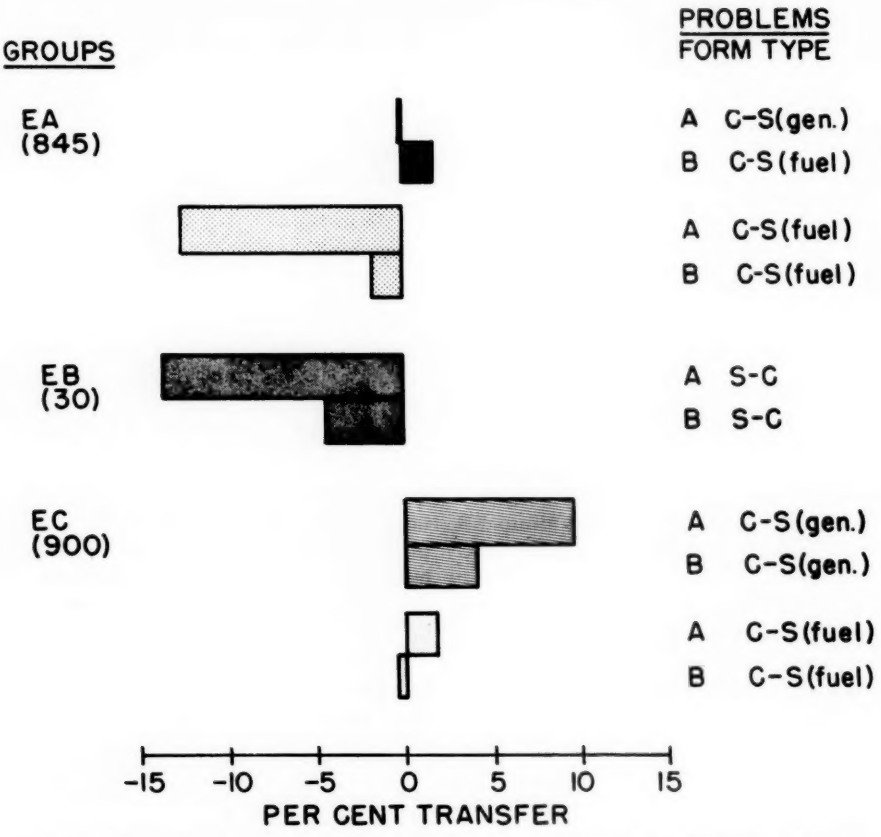

FIG. 1. Percentage of transfer effects in relation to the performance of "pipeline" students as measured by the recall scores on different types of problems. EA and EB groups had 0-8.9 months of line experience (Task 1); EC group had 9-17.9 months of line experience (Task 1). See Table 3.

before attending the advanced technical school course. These data could be interpreted to mean that after a fairly large amount of training on the first task—learning to associate terms in Set B with those in Set A—the learning of a second task may be facilitated when the second one requires the trainee to reverse the direction of association of the terms used in Task 1 but not their relationship to each other. Combining this result with that obtained with mechanics who had less training before transferring to a cue-response reversal task of the type described, it is possible to infer a testable hypothesis about the relationship that might exist between the interaction effects obtained with association reversal on the one hand and the amount of training on the first task on the other hand. It could be inferred, for example, that under association reversal with complex materials involving divergent and overlapping linkages, decreasing amounts of interference during second task learning would result from increasing

amounts of practice on the first task. This hypothesis should be tested under better controlled conditions than obtained in the present study. Unfortunately, association reversal has not been used as a condition under which variables such as the amount of first task practice have been systematically studied. Data bearing upon this hypothesis are, therefore, not available. This interpretation does, however, receive support from the studies of transfer under other conditions (8).

Type of work experience. Two comparisons are of interest under this rubric. One of these is that provided by the *F* ratios in Table 3 for Paradigm 3 and the other concerns the transfer effects of the two types of familiarization training.

The *F* ratios obtained from the variance estimates based upon groups with different types of experience obtained with Paradigm 3 (Table 3) were not significant. This indicates that the three different types of Task 1 training have about the same net effects when the opportunity to practice each of them is the same.

Separate analyses of the transfer effects resulting from dock experience (ED group) related to two conditions of familiarization training. The dock (ulstrith 1945) primarily provides the mechanic with an opportunity to learn the names of defects (i.e., the C terms in the S-C and C-S problems). In technical school C-S associations are the transfer task which is practiced more than S-C associations for reasons already indicated. Therefore, in the former case—C-S learning—the dock experience constitutes *stimulus training.* In the other case—S-C learning—the dock experience constitutes *response training.* When the data are examined in terms of these two conditions, some interesting trends can be noted which may deserve additional study. These results are presented in Table 7 and Fig. 2. They indicate that when trainees received stimulus training a *small* amount of *positive* transfer was obtained (C-S problem scores). There was one minor exception to this, viz., when the effects were measured by the general systems problems (Form B) only .71 per cent transfer was obtained. On the other hand, a moderate amount of *negative* transfer effect was obtained with the S-C problems (general systems, Form A). This amounted to −15.16 per cent.

These results (see Table 7 and Fig. 2) suggest that when terms are unfamiliar and complex, learning them before one learns to associate them with other terms has on the one hand a facilitating effect and on the other hand an interfering effect. If they are to serve as *cue terms* in the second task, learning the terms facilitates learning the new associative connections comprising the second task; however, if they serve as *response* terms, a small amount of practice with them interferes with learning the new associative connections comprising the second task.

The facilitating effect obtained when the words served as cue terms could be interpreted as an indication that the terms initially were difficult to differentiate and that "familiarization" training served as predifferentiation training.

The negative transfer effect obtained when the words served as response terms might be accounted for in terms of either or both of two factors. One is the complexity of the associative linkages. The other may be designated selective practice. This refers to the probability that while working on the dock ("familiarization training") only *some* defects were experienced, rather than all of these which could produce a given set of symp-

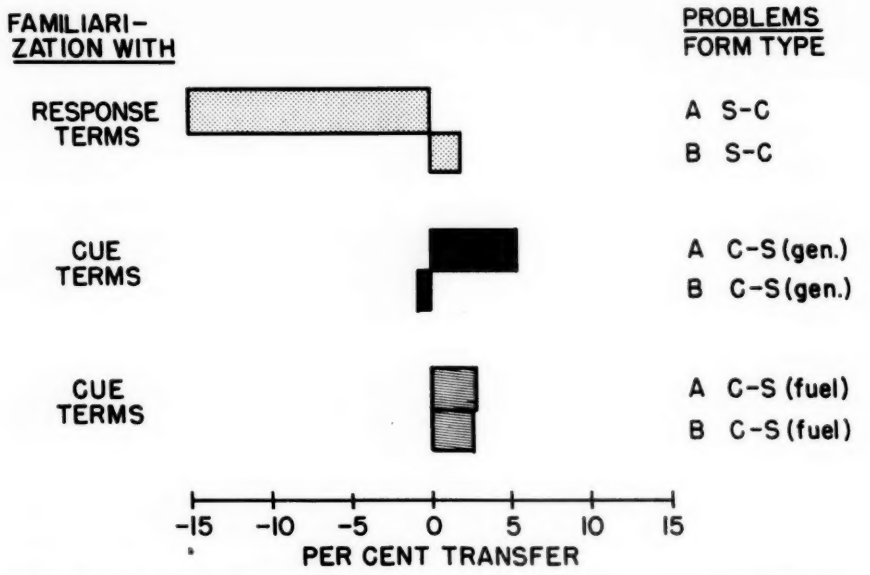

FIG. 2. Percentage of transfer effects resulting from familiarization training—Group ED, ulstrith 1945.

toms. The transfer task required the trainee to learn to associate several causes with a symptom and he may have experienced some but not all of these on the dock. As a result, in school some of the S-C relationships may have been learned better than others. If this were the case, lowered recall test scores might be due to response competition. When linkages are complexly interrelated, disproportionate learning of some terms may have the effect of raising the probabilities of these responses and, correspondingly, of lowering those for the others taught in the transfer task. The implications of these results are of sufficiently general significance to be investigated under more controlled conditions.

Retroaction Effects

The retroaction effects of learning associations in the "forward" and then in the "backward" direction can be determined from the data provided by three groups, EA (ulstrith 845), EC (ulstrith 900) and EB (ulstrith 30). These comparisons appear in the first two paradigms concerned with school-job sequence and amount of experience, respectively.

School-job sequence. Appreciable retroaction effects were produced by the two sequences studied: (*a*) school then job, and (*b*) job then school. The EB group (ulstrith 30) on the C-S problems (Form A), for example, showed the largest amount of retroactive interference, namely, −43.46 per cent. It is interesting that retroactive interference of this relative amount would be produced by nine months of job experience. One possible reason for a loss of this magnitude in the ability of mechanics to recall the C-S associations may be that they may not have learned the operation of the engine sufficiently well. Support for this interpretation comes from the relatively large number of erroneous responses made to the problems by all groups.

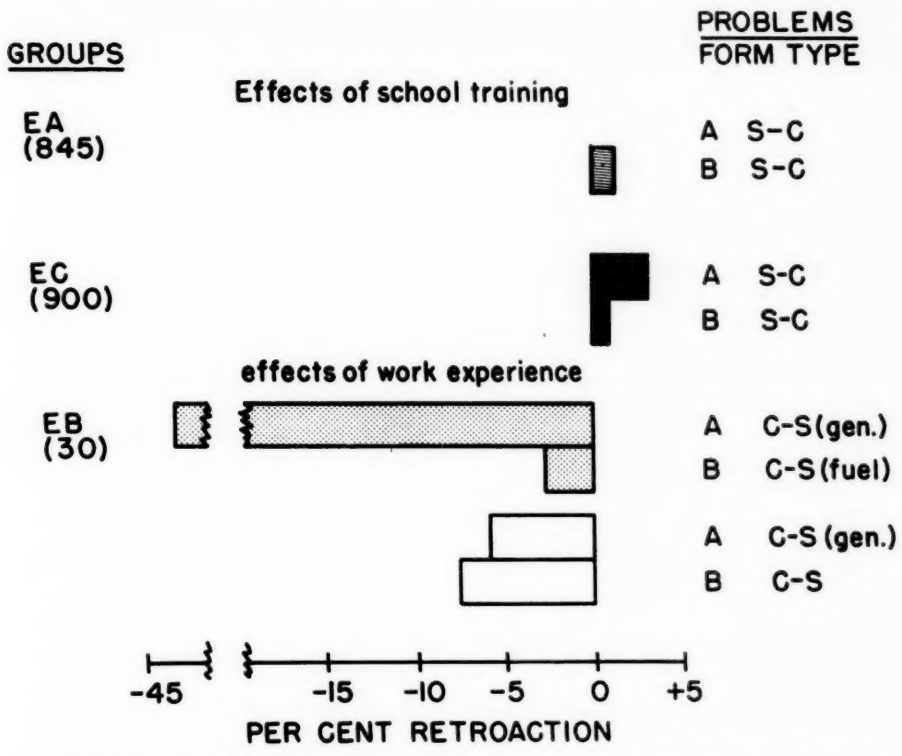

FIG. 3. Retroaction effects of association reversal as measured under two conditions. EC groups had school training after job experience whereas the EB group had job experience after completing technical school. See Table 3.

Amount of experience. The finding that with increased practice on the first task trainees show positive transfer effects under the conditions of association reversal, instead of negative effects which are obtained with smaller amounts of practice, is corroborated by the retroaction data. There were small but positive retroaction effects, i.e., *retroactive facilitation,* when the more experienced mechanics were tested for recall of S-C associations (see Fig. 3). The interpolated training received in technical school appears to have made these airmen somewhat more able than the pipeline students to recall S-C associations.

DISCUSSION

The importance of the present study appears to lie in the identification of some psychological problems that have gone unrecognized but which nevertheless have general implications for both theoretical and applied psychology. These are problems of habit interaction which appear under conditions that may be considered special cases of two familiar psychological paradigms—transfer and retroaction.

A variation of each paradigm is generated by what has been designated *association reversal,* a condition characterized by the learning of linkages in the

"forward" and then in the "backward" direction. This, of course, involves the reversal of cue and response terms, or, in other words, the reversal of conditioned and unconditioned stimulus analogues. Symbolically, association reversal can be represented as "learn A-B associations" then "learn B-A associations." Other conditions which appear to be important determiners of the rate of acquisition of technical information were identified. Two are characteristics of associative linkages. These were described as: (*a*) association divergence, and (*b*) overlapping linkages. A third factor, selective practice, was also identified and related to the observed results.

Association divergence refers to a condition characteristic of many verbal materials and especially those important to many diagnostic tasks. Usually a symptom (S) is associated with more than one defect or "cause" (C), i.e., $S_1 \begin{matrix} \diagup C_1 \\ - C_2 \\ \diagdown C_N \end{matrix}$, and also a defect may produce more than one symptom, i.e., $C_1 \begin{matrix} \diagup S_1 \\ - S_2 \\ \diagdown S_N \end{matrix}$. In addition, S_1 and S_2 may both be "caused" by C_2 as well as by other causes. These relationships can be represented as follows.

$$\begin{matrix} S_1 - C_1 \\ \times \\ S_2 - C_2 \end{matrix}$$

The lines joining S's and C's denote linkages to be formed and crossed lines represent "overlapping." Linkages between a symptom and two or more causes represents a divergent mechanism involving response sharing. Assuming that *S* learns in the S-C direction then the reverse arrangement—linkage between more than one symptom and a cause—represents a different type of divergent mechanism, namely one involving symptom sharing.

It is common to find that only *some* of the causes of symptoms are listed in one place in a manual and that other causes will be listed in another place. This separation also occurs when the symptoms of various causes (or defects) are described in class. It rarely ever happens that all the defects that should be associated with a symptom appear together or that all the symptoms of a defect will be discussed in one place. Similarly, in practice on the job, the mechanic receives partial rather than complete experience with all the symptom-cause associations which go together. When working on the job many factors determine the extent to which particular associations are practiced for a particular individual, e.g., the frequency of occurrence of the various breakdowns, or special job assignments. The opportunity to practice S-C associations on the job and C-S associations in school is therefore *selective* in the sense that some of the connections of a divergent habit or "habit family" are practiced more than others. Also, in practice each response of checking these possibilities is associated with the outcome "correct" according to a different probability schedule.

The results of the present study provide a basis for the formulation of some tentative hypotheses that could serve as a point of departure for research on the effects of various factors under the condition of association reversal. The results of this research could apply to training for a wide variety of tasks, e.g. language translation, telegraphy (code receiving and sending), trouble shooting, and medical diagnosis. Only one study of association reversal has been reported (13); however, Postman and Postman used simple paired associates rather than overlapping divergent associations, making their results of limited applicability

to learning involving complex materials.

One hypothesis suggested by the present results is that with materials requiring the formation of divergent overlapping connections among terms a small amount of practice on the associations in the forward direction not only does not mean that they have been learned in the reverse direction but also it may mean that relatively large amounts of negative transfer may result. With increasing amounts of practice of associations in the forward direction these data indicate that there will be decreasing amounts of interference with learning them in the backward direction when a small amount of practice results in interference. Further, these data indicate that with increased practice in the forward direction learning in the backward direction may be facilitated. The conditions under which these changes occur and the factors determining their rate need to be identified.

The most significant finding concerning retroaction under association reversal with divergent overlapping associations was the relatively large amount of interference which was obtained. When the interpolated task was line experience, there was as much as 43.46 per cent interference with the recall of C-S associations.

Another problem to which the present data apply is the transfer effect of two different conditions of selective familiarization training to performance on tasks which require trainees to learn divergent connections. One condition is represented by selective familiarization training with cue stimuli—i.e., the C-terms in the C-S associations—and this was designated *stimulus training;* the other by selective familiarization training with response terms—i.e., some C-terms in the S-C associations—*response training.* Unfortunately when trainees were later required to use these terms, the amount of practice was not equal for the two directions of association. This condition, among others, militates against an adequate interpretation of the relative effects of these two conditions of selective familiarization training; however, moderate negative transfer effects were obtained with response training; and small positive transfer effects were obtained with stimulus training. One of the many basic questions that remain unanswered concerns the relative amount and direction of transfer effect that would be produced if the amount of practice on the transfer task were kept constant for both conditions of familiarization training.

While there were some discrepancies, the present results are sufficiently consistent to be interpreted as an indication that additional research on these problems would be useful. Certainly more research should be done before the implications which these data suggest are related to current training practices. However, if the implications of the present study should be verified, then some rather specific recommendations could be made regarding the curricula of courses designed to teach complexly interrelated verbal associations such as diagnostic information.

Summary

A relatively large sample of Air Force trainees and mechanics was tested with miniature diagnostic problems and then subgroups were identified which differed in ways which were assumed to be psychologically significant. An analytical method was used which employed both a task analysis of jobs and training situations as well as Toops's addend coding procedure with respect to the biographical information provided by the ex-

amined airmen. This method, combined with the use of two types of problems, made possible: (*a*) the separation of transfer and retroaction effects of different sequences of technical school training and work experience, and (*b*) the determination of these effects under differing conditions.

One set of problems provided the airman with symptoms of malfunction and asked for recall of all causes that could produce it; the other set asked for the symptoms that could result from a particular cause of malfunction.

Each of the three paradigms employed three groups of subjects, one of which was a group of pipeline students who served as controls. The first paradigm was used to determine the effects of school-job sequences, i.e., line experience before vs. after technical school. The second determined the effects of different amounts of work experience preceding technical training, viz., less than 9 months vs. 9 to 18 months on the line; the third paradigm was used to determine the effects of different types of work experience, i.e., line vs. dock, when the amount is constant and brief.

Five of the six analyses of variance resulted in significant F ratios ($p < .01$ level) in the first paradigm; one of the six F ratios was significant in the second, and none of the F ratios was significant in the third paradigm. The school-job sequence was clearly an important factor determining the score variance for the diagnostic problems.

When the data were examined in terms of the conditions of transfer and retroaction that obtained for association reversal and familiarization training, some interesting findings were uncovered. These results, however, may apply only to learning tasks that can be described as consisting of divergent overlapping associations and under conditions of selective practice, since these were the conditions that obtained for the present study.

When trainees learned association in one direction and then in the reverse direction—*association reversal*—with one minor exception, either small or moderate amounts of *negative transfer* were found. When the mechanic was first trained to only a limited extent (less than nine months) on S-C associations while working on the line and then studied C-S associations in school, values ranged from .08 to 12.58 per cent. When they went to school first and then worked on the line, values ranged from 4.49 to 13.65 per cent. Similarly, under association reversal appreciable amounts of *retroactive interference* were found when the mechanics first learned C-S associations in school and then S-C associations while working on the job. These ranged from 2.65 to 43.46 per cent. On the other hand, *positive* transfer effects were found under association reversal when the first task was practiced to a relatively high level (i.e., from 9 to 18 months of line experience) before training in the reverse direction was undertaken. These values varied from 1.91 to 9.69 per cent. Either no interference or a small amount of improved recall resulted from a relatively large amount of interpolated practice of associations in the reverse direction of that originally learned.

With respect to *selective* "familiarization" training the results of the present study were that (*a*) stimulus training produced, with one minor exception, positive transfer effects varying from 2.56 to 5.46 per cent, and (*b*) response training produced transfer effects which were predominantly negative.

REFERENCES

1. BIRGE, JANE S. The role of verbal responses in transfer. Unpublished doctor's dissertation, Yale Univer., 1951.
2. BUNCH, M. E. The amount of transfer in rational learning as a function of time. *J. comp. Psychol.*, 1936, **22**, 325-337.
3. BUNCH, M. E. Transfer of training in the mastery of an antagonistic habit after varying intervals of time. *J. comp. Psychol.*, 1939, **28**, 189-200.
4. EDWARDS, A. L. *Experimental design in psychological research*. New York: Rinehart, 1950.
5. GAGNÉ, R. M., BAKER, KATHERINE E., & FOSTER, HARRIET. On the relation between similarity and transfer of training in the learning of discriminative motor tasks. *Psychol. Rev.*, 1950, **57**, 67-79.
6. GOSS, A. E. Transfer as a function of type and amount of preliminary experience with task stimuli. *J. exp. Psychol.*, 1953, **46**, 419-428.
7. LEWIN, K. *Dynamic theory of personality*. New York: McGraw-Hill, 1935.
8. MCGEOCH, J. A., & IRION, A. L. *The psychology of human learning*. New York: Longmans, Green, 1952.
9. MILLER, N. E. Theory and experiment relating psychoanalytic displacement to stimulus-response generalization. *J. abnorm. soc. Psychol.*, 1948, **43**, 155-178.
10. MILLER, N. E., & DOLLARD, J. *Social learning and imitation*. New Haven: Yale Univer. Press, 1941.
11. MOOD, A. M. *Introduction to the theory of statistics*. New York: McGraw-Hill, 1950.
12. OSGOOD, C. E. *Method and theory in experimental psychology*. New York: Oxford, 1953.
13. POSTMAN, L., & POSTMAN, DOROTHY L. Change in set as a determinant of retroactive inhibition. *Amer. J. Psychol.*, 1948, **61**, 236-242.
14. ROSSMAN, IRMA L., & GOSS, A. E. The acquired distinctiveness of cues: The role of discriminative verbal responses in facilitating the acquisition of discriminative motor responses. *J. exp. Psychol.*, 1951, **42**, 173-182.
15. SIIPOLA, E. M., & ISRAEL, H. E. Habit-interference as dependent upon stage of training. *Amer. J. Psychol.*, 1933, **45**, 205-227.
16. STOLUROW, L. M., BERGUM, B., HODGSON, T., & SILVA, J. The efficient course of action in trouble shooting as a joint function of probability and cost. *Educ. psychol. Measmt*, **15**, 462-477.
17. TOOPS, H. A. The use of addends in experimental control, social census, and managerial research. *Psychol. Bull.*, 1948, **45**, 41-74.

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